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SITAEL AT-1K ARCJET

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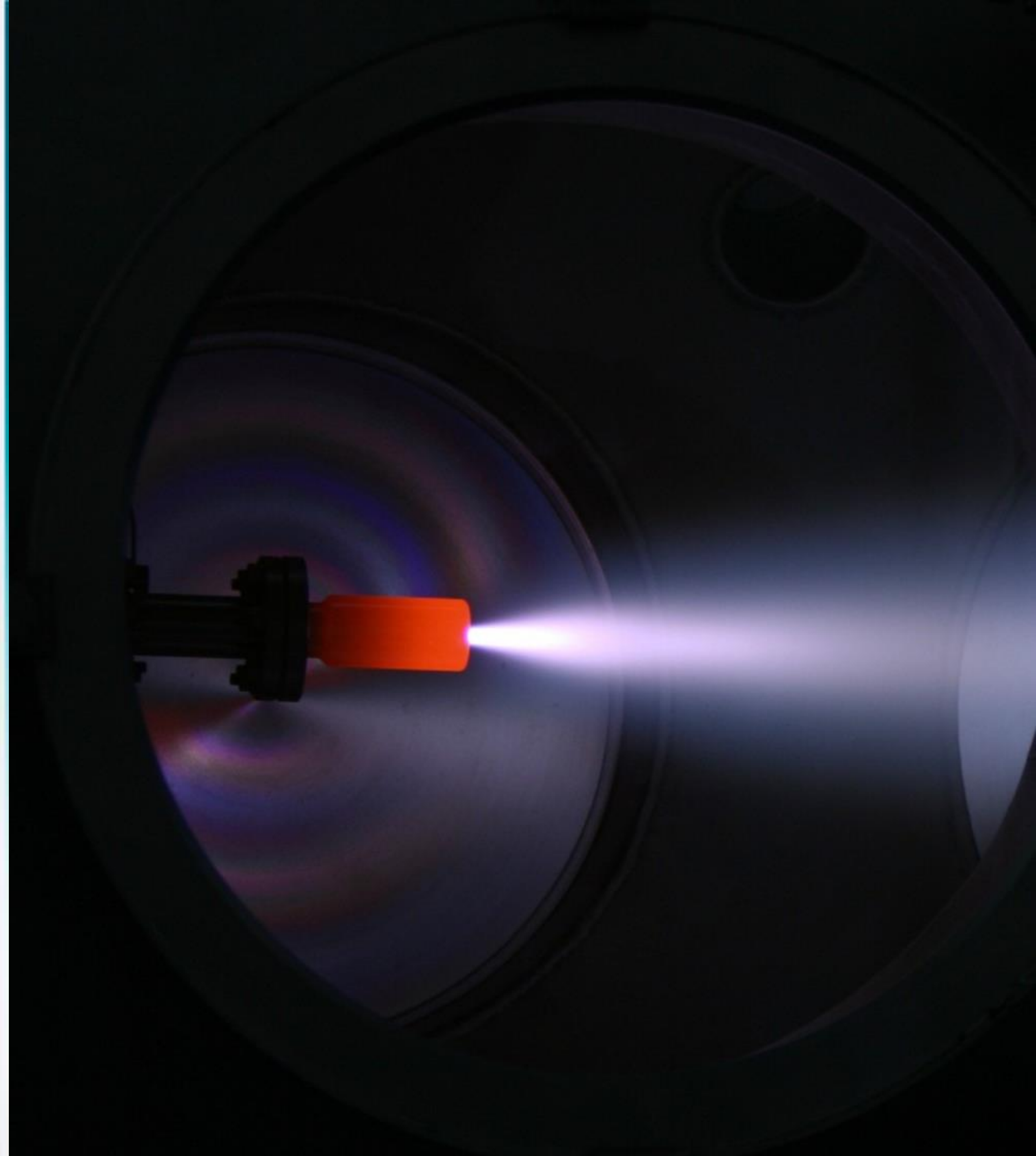
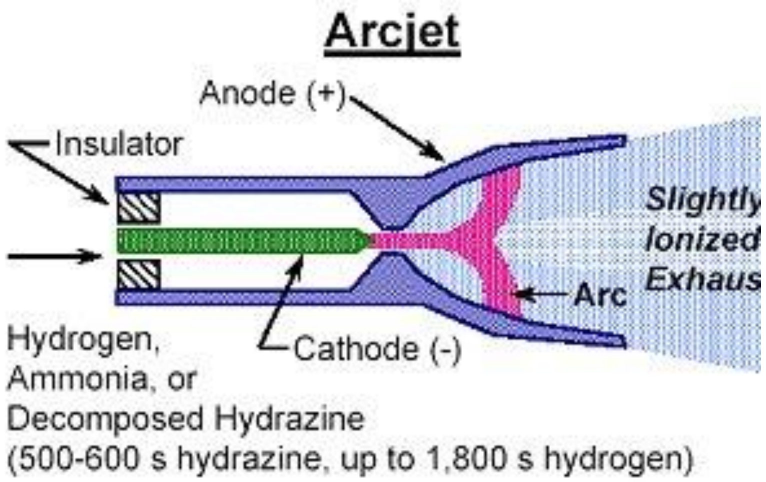


Arcjet Working Principle

The **Arcjet thruster** belongs to the family of **electro thermal thrusters:**

- the working fluid undergoes a classical gas-dynamic acceleration;
- the fluid is heated directly by an electrical discharge (arc) between a coaxial electrode (cathode), placed upstream the nozzle throat (constrictor) and the nozzle itself (anode).

AJ developers: Aerojet (flight heritage), SITAEL, IRS, Plasmadyne, Osaka University, LeRC, BICE.



SITAEL AT-1k Arcjet

SITAEL starting point is the existing **AT-1k arcjet**, developed since the late ’90s and optimized in the past three years with helium, argon, xenon, nitrogen or mixtures of nitrogen and hydrogen as propellants. Even if not directly tested with hydrazine, AT-1k compatibility with blends of nitrogen and hydrogen makes it suitable also for this propellant.

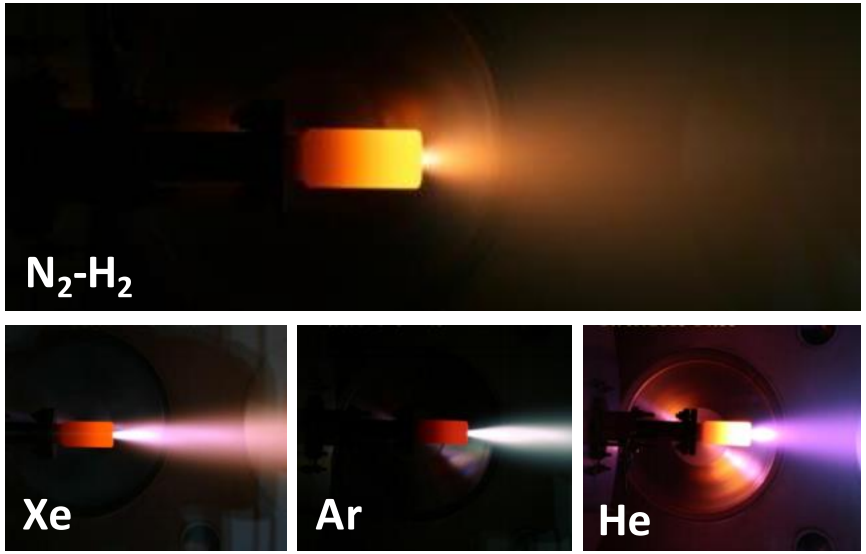
The **SITAEL AT-1k arcjet** is designed for a wide range of applications:

- Orbit raising;
- Controlled or semi-controlled re-entry at EOL;
- EOL graveyard repositioning;
- Collision avoidance;
- Reaction wheels desaturation.

SITAEL AT-1k Arcjet

Main SITAEL activities on **AT-1k**:

- AT-1k **characterization** with Xe, Ar, He and **N_2-H_2** mixture;
- Assessment of AJ **lifetime** (throat erosion) by test;
- More than **100 h** firing (cumulated);
- AJ **PPU design** and development;
- Arcjet based Propulsion Subsystem (**APS**) design (**CS BB25**).



AT-1k main specifications	
Propellant	Ar, He, Xe, N_2, H_2, blends
Power	1 kW
Operating Voltage	– Operational: 30-90 V – Ignition: 150 V
Operating Current	10-20 A
Feeding Pressure	0.8-3 bar
Thrust	Up to 150 mN
Specific impulse	Up to 600 s
Thruster Efficiency	Up to 50%
Thruster Mass	< 1.2 kg

CS BB25: Introduction

In the frame of the **ESA CleanSpace** (CS) project (**BB25**), SITAEL activities have been focused on the following areas:

- Assessment of the main **Arcjet based Propulsion Subsystem** (**APS**) **requirements** in accordance with the Large System Integrator (LSI);
- **APS architectural design**, including trade-off analyses, suitable COTS selections, analysis and design of customized components and system impact at spacecraft level;
- **APS performance**, mass, power, cost **budget** evaluations;
- **APS reliability** evaluation at EOL;
- **APS demisability** evaluation;
- **APS development plan** analysis.

CS BB25: LSI Requirements

Requirement topic	CASE #1	CASE #2
S/C mass	800 kg	1500 kg
Main operating media	Hydrazine, LMP-103S (green prop.)	Hydrazine, LMP-103S (green prop.)
Thruster Input Power	Up to 1 kW	Up to 3 kW
Thrust level	≥ 100 mN	≥ 300 mN
Specific impulse	≥ 400 s	≥ 600 s
Thruster mass	≤ 1.2 kg	≤ 1.2 kg/kW
Mission and total impulse	90-120 kNs – Nominal operation – Uncontrolled re-entry	700 kNs – Orbit raising – Controlled re-entry
Enviroment	Total ionizing dose; atomic oxygen fluence; mechanical and thermal env.	Total ionizing dose; atomic oxygen fluence; mechanical and thermal env.
Design and functional	System reliability, mass and cost; materials; flow barriers.	System reliability, mass and cost; materials; flow barriers.

CS BB25: Trade-off (1/2)

Hydrazine vs LMP-103S

- Thrust @ fixed MFR and power: hydrazine > LMP-103S (≈10-31% lower)
- Isp: hydrazine > LMP-103S (≈9-31% lower)
- Lifetime, No. cycles: hydrazine > LMP-103S
- Development time: hydrazine < LMP-103S
- Handling difficulties: hydrazine > LMP-103S
- Risk of concept failure: LMP-103S >> hydrazine

Blowdown vs pressure regulated

- Performance (optimization and stability): blowdown < pressure regulated
- Weight and volume benefits: blowdown > pressure regulated
- Recurrent cost: blowdown < pressure regulated

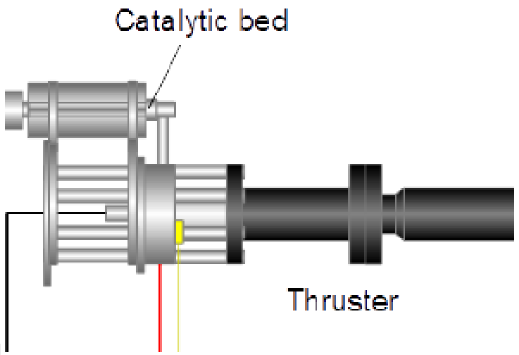
CS BB25: Trade-off (2/2)

AT-1k cluster vs AT-3k (CASE #2)

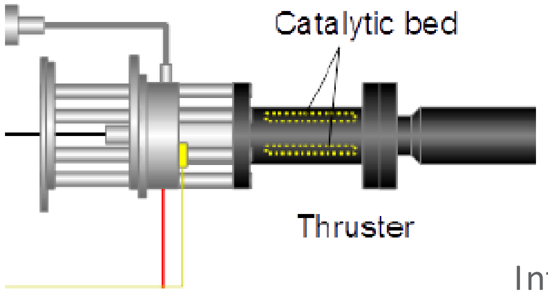
- Performance: 3 kW single thruster > cluster of 1 kW thrusters
- Thruster unit mass: cluster ≈ 1.8 x 3kW single thruster
- Recurrent cost: 3 kW single thruster < cluster of 1 kW thrusters
- Target reliability: cluster of 1 kW thrusters > 3kW single thruster

Catalytic bed integration in the thruster body

- Heavy design modifications due to the interaction between the thruster hot part and the catalytic bed components (catalyst and heater)
- Risk of concept failure during the development phase



Non-integrated



Integrated

CS BB25: Results

CASE#1 – 800 kg platform

- **AT-1k** thruster as baseline
- Propellant: **hydrazine**
- **Pressure regulated** system
  - Blowdown option could be considered in case of more stringent requirements on mass and envelope
- Non-integrated catalytic bed

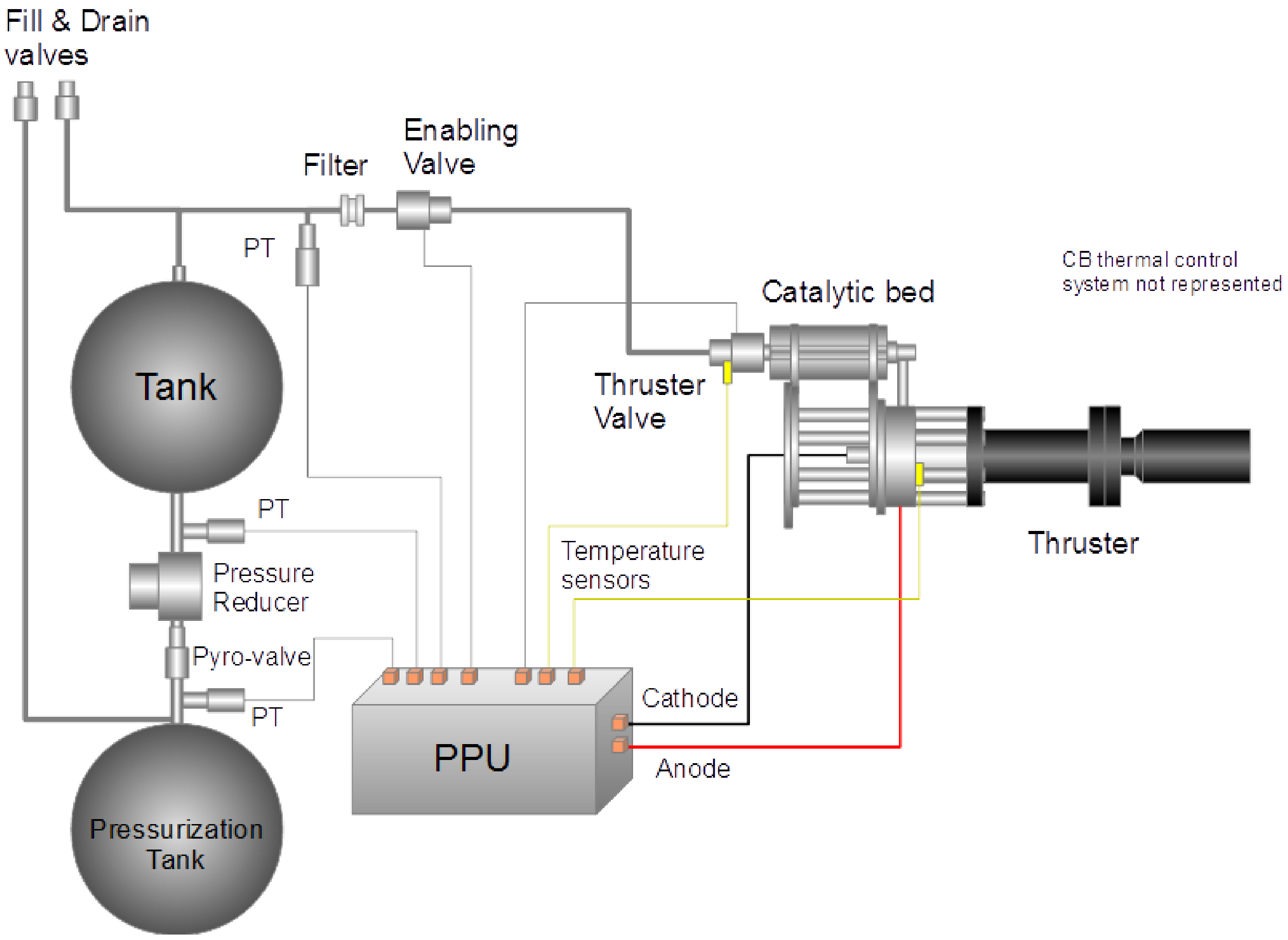
CASE#2 – 1500 kg platform

- **AT-3k** thruster (scaled version of AT-1k) as baseline
- Propellant: **hydrazine**
- **Pressure regulated** system
- Non-integrated catalytic bed

CS BB25: APS Configuration

The APS is composed by:

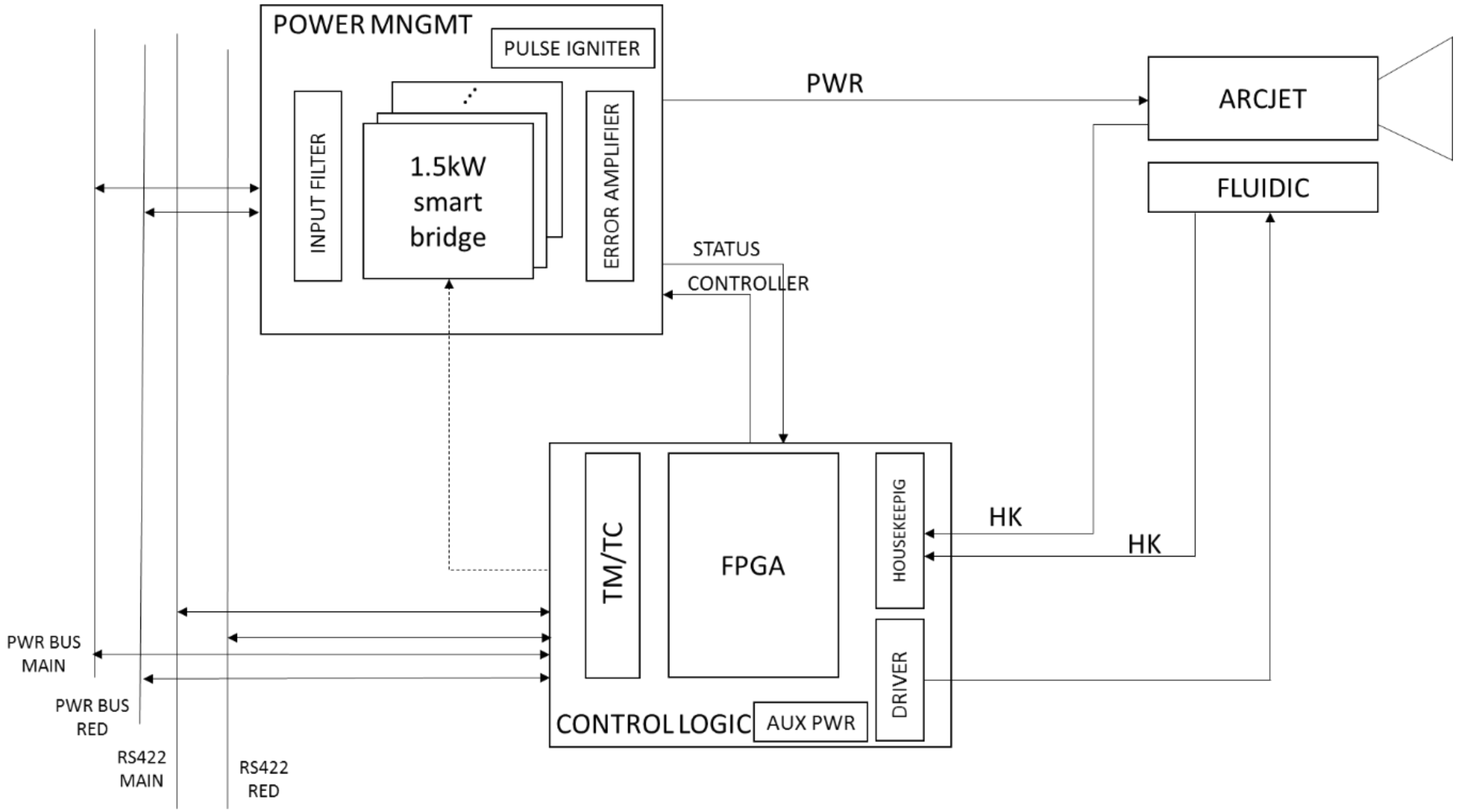
- **Arcjet Thruster Unit (TU)**: thruster, gas generator and the thruster valve.
- **Feeding system**: sensors (pressure and temperature), valves, filters and pressure regulator or pressurization system.
- **Power Processing & Control Unit (PPU)**: control board, power modules and ignition circuitry.



CS BB25: PPU General Architecture

PPU main characteristics:

- **Modular power units**, based on the evolution of the 1.5kW smart bridge module developed for HETs
- Dedicated **ignition board** with active impedance adapter
- Dedicated **Power Control Unit** based on FPGA architecture
- **Full redundant** - high reliable architecture



CS BB25: Mass and Power Budgets

Mass and power budgets for both **1kW** and **3kW** systems have been estimated considering representative **COTS** components.

	CASE #1	CASE #2
Thruster Unit [1]	1.1 kg	2 kg
PPU [2]	6 - 8 kg	9 - 10 kg
Feeding system [3]	1.4 kg	1.4 kg
Harnesses	1.6 kg	2.4 kg
Total mass	10.1 - 12.1 kg	14.8 – 15.8 kg

Note
[1] Including AT-1k, gas generator and valve
[2] According to the PPU internal redundancy level
[3] Without tank and pressurization system

	CASE #1	CASE #2
Thruster Unit	1020 W	3020 W
PPU	73 W	179 W
Feeding system	25 W	25 W
Total power consumption	1118 W	3224 W




CS BB25: APS Development Plan

Model philosophy:
- **TU**: 2 EQM, 1 PFM
- **PPU**: 1 BBM, 2 EQM, 1 PFM
- **Feeding system**: 2 EQM, 1 PFM

Test philosophy:
- Validation test on BBM, EQM
- Coupling test on EQM
- Acceptance test on PFM

	AT-1k Hydrazine	AT-1k LMP-103S
KOM	T0	T0
SSR	T0+4	T0+4
PDR	T0+8	T0+16
EQM TRR	T0+12	T0+20
ΔPDR	T0+27	T0+37
CDR	T0+30	T0+39
PFM MRR	T0+34	T0+43
Acceptance Review	T0+40	T0+49

The overall schedule for LMP-103s is longer with respect to hydrazine due to the development time needed for the gas generator and the compatibility tests with materials.

Conclusions

- SITAEL **AT-1k arcjet** has been **developed** and **characterized** with different propellants in the last five years
- In the frame of **CS BB25** study, the Arcjet based Propulsion Subsystem (**APS**) has been **designed** and the main APS **performance** has been assessed
- According to the **LSI** requirements, the SITAEL proposed APS is suitable for **application** on **medium platform** for both nominal and **end-of-life** maneuvers

Thanks for your attention

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